

CORRELATION BETWEEN PHYSICAL AND CHEMICAL INDOOR AIR QUALITY WITH RESPIRATORY HEALTH

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Abstract

Introduction: Indoor air quality (IAQ) refers to the quality of air within enclosed spaces, which makes up most of the air inhaled daily. Pneumonia is reported to be 17.33 times more common in children living in unhealthy households than those in healthy homes. This study examined the relationship between physical and chemical indoor air quality and children's respiratory health in the working area of the South Krembangan Community Health Center in Krembangan Subdistrict, Surabaya City. **Methods:** This study employed an analytical observational design utilizing a case-control approach. Samples were selected through purposive sampling. A total of 54 respondents participated in this study, consisting of 27 cases and 27 controls. **Results and Discussion:** The findings demonstrated a strong correlation between the prevalence of pneumonia in children and air quality parameters including room temperature, humidity, $PM_{2.5}$ concentration, lighting intensity, and ventilation area. Room temperature ($p = 0.029$), humidity ($p = 0.049$), $PM_{2.5}$ ($p = 0.014$), lighting intensity ($p = 0.006$), and ventilation area ($p = 0.028$) all showed statistically significant correlations. Formaldehyde (HCHO), on the other hand, did not significantly correlate with the incidence of pneumonia ($p = 0.569$). Additionally, total volatile organic compounds (TVOCs) and carbon monoxide (CO) were found to be below the Environmental Health Quality Standards. **Conclusion:** Although many housing conditions already fulfil established criteria, it is advised that factors potentially affecting indoor air quality be taken into consideration.

INTRODUCTION

Most of the air inhaled by humans originates from indoor environments during daily human activities. Indoor air quality (IAQ) parameters encompass three aspects: physical, chemical, and biological. Environmental factors, including indoor air conditions, constitute one of the major global public health concerns (1). This is due to the significant amount of time individuals spend indoors. People can spend up to 80–90% of their time within enclosed spaces, which can ultimately lead to health problems that can arise from exposure to indoor air pollutants (2). Physical IAQ parameters include temperature, relative humidity, and ventilation. Chemical

parameters, including volatile organic compounds (VOCs), formaldehyde, particulate matter ($PM_{2.5}$), and carbon dioxide (CO_2), are known to affect the respiratory system (3). Previous research has revealed a correlation between respiratory symptoms and the growth of physical mold due to water damage and moisture accumulation in school building materials (4).

In urban areas of Indonesia, a high incidence of acute respiratory infections (ARIs) has been reported, and this condition is closely linked to exposure to poor air quality in enclosed environments, such as indoor workspaces or housing (5). Children represent a vulnerable group to many health impacts, including those

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related to air pollution. This is influenced by the fact that their immune systems are still developing. Another factor is the large amount of time children spend indoors, such as during playing activities at home and learning activities at school. This makes children particularly vulnerable to indoor air pollution (6). Although many studies have examined indoor air quality parameters from physical or chemical aspects separately, in reality there are still few studies that discuss the correlation between these two parameters and their impact on the health of building occupants (7). Therefore, this study aims to analyze the correlation between physical and chemical indoor air quality parameters and the respiratory health of children in the working area of the South Krembangan Community Health Center, Krembangan Subdistrict, Surabaya City.

Pneumonia accounted for 14% of all deaths among children under five years of age, resulting in 740,180 deaths globally in 2019 (8). Indonesia ranks eighth among the 15 countries with the highest pneumonia-related mortality, with approximately 22,000 deaths reported. According to the 2022 Indonesian Health Profile, pneumonia is the main cause of death in infants aged 29 days to 11 months or commonly referred to as the post-neonatal period, where they contribute 15.3% of total deaths, and also contribute significantly to the mortality rate in toddlers aged 12–59 months (12.5%) (9). Data from the East Java Provincial Health Office, specifically the Disease Prevention and Control Section, reported that the number of pneumonia cases in children under five was 75,632, of which 51.37% occurred in boys and the remainder (46.3%) in girls (10). Severe pneumonia accounted for 1,571 cases, of which 56.14% occurred in males and 43.86% in females. According to data reported in 2022 by the Central Statistics Agency (BPS) of East Java, there were 11,692 cases of pneumonia. Childhood represents a critical period of growth and development that occurs rapidly and cannot be repeated (11). Evidence from previous research indicates that the risk of developing pneumonia in children living in unhealthy homes is 17.33 times greater than in those living in decent homes and healthy environments (12). A home environment that does not meet health standards and is not kept clean can become a pathway for the growth and transmission of bacteria, viruses, and microorganisms, which can act as causative agents of acute respiratory infections in humans, especially children.

METHODS

This study took place in the working area of the South Krembangan Community Health Center from January to March 2024. A quantitative study was

conducted, using an observational analytical approach with a case-control study design. Purposive sampling resulted in a total sample of 54 children, consisting of 27 cases and 27 controls. The case group was defined as toddlers diagnosed with pneumonia and registered as patients in the South Krembangan Community Health Center during the February-March 2024 period. Meanwhile, the control group consisted of toddlers not diagnosed with pneumonia. Data collection was carried out through questionnaire-guided interviews, environmental measurements, and direct observations.

The research variables were categorized into dependent and independent variables. The dependent variable studied was children under five years of age with pneumonia, which was assessed through interviews and recorded using a nominal scale with two categories: (1) no pneumonia and (2) pneumonia. The independent variables were grouped into two categories. The first category consisted of physical indoor air quality factors, which included parameters such as temperature, humidity, lighting, and ventilation. All parameters were measured using appropriate instruments and categorized using a nominal scale as either meeting or not meeting the specified requirements. The second category comprised chemical indoor air quality factors, including PM_{2.5}, CO, formaldehyde (HCHO), and TVOCs. All three chemical parameters were measured using appropriate instruments and categorized using a nominal scale as either meeting or not meeting the specified requirements. The determination of parameters in this study was based on the air quality parameters contained in the Regulation of the Minister of Health Number 2 of 2023 which governs the technical implementation of Government Regulation Number 66 of 2014 concerning Environmental Health. Primary data were collected directly through measurements of each parameter. Indoor air quality measurements, including temperature, humidity, HCHO, PM_{2.5}, and TVOCs were conducted using a Borsean Air Quality Detector between 09:00 and 13:00. In addition, secondary data were collected through a review of relevant literature including journals and books that support the research topic, as well as from existing document sources available at the South Krembangan Community Health Center.

Primary data obtained from field measurements were analyzed in accordance with the requirements stipulated in the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 which governs the implementing regulation of Government Regulation Number 66 of 2014 concerning Environmental Health. Data analysis was carried out with the help of SPSS 16 software, including univariate analysis to describe each

research variable and bivariate analysis to examine the correlation between two variables. The chi-squares statistical test was used in the bivariate analysis with a significance level (α) of 0.05. Hypothesis testing was based on the level of significance (p-value) obtained from the chi-squared test, where a p-value ≤ 0.05 indicated a correlation between the two variables studied. An odds ratio (OR) value less than 1 indicated a protective risk factor with an effect, an OR value of greater than 1 indicated a risk factor, and an OR value equal to 1 indicated no risk factor. OR is useful for measuring the strength of the correlation between a risk factor and a health effect, particularly in case-control studies. It shows how much greater the likelihood of exposure is in the case group compared to the control group.

RESULTS

Pneumonia is one of the most common and dangerous infectious diseases, especially among children under five years of age. This disease can be caused by various factors, including chemical air pollutants such as $PM_{2.5}$, carbon monoxide (CO), formaldehyde (HCHO), and volatile organic compounds (VOCs), as well as physical factors such as temperature, ventilation, lighting, and humidity. Exposure to these factors can affect children's respiratory health, increasing the risk of pneumonia.

Frequency Distribution

Measurements of the physical and chemical indoor air quality parameters were conducted in each respondent's home. The physical parameters consisted of ventilation area, lighting, humidity, and temperature. Meanwhile, chemical parameters consisted of $PM_{2.5}$, CO, TVOCs, and HCHO. The measurement results for the physical and chemical indoor air quality parameters are presented in Table 1.

Table 1. Frequency of Physical and Chemical Indoor Air Quality Parameters

Variable	Qualified		Unqualified		Total
	n	%	n	%	
Room temperature	25	46.3	29	53.7	54 (100%)
Humidity	20	37	34	63	54 (100%)
$PM_{2.5}$	26	48.1	28	51.9	54 (100%)
CO	54	100	0	0	54 (100%)
TVOC	54	100	0	0	54 (100%)
HCHO	35	64.8	19	35.2	54 (100%)
Lighting intensity	27	50	27	50	54 (100%)
Ventilation area	31	57.4	23	42.6	54 (100%)

Table 1 shows that 53.4% of respondents' houses had temperatures that met the requirements. Based on observations, the average indoor air temperature was

30.27°C, which may be influenced by the proximity of the study area to the coastal region. In addition, high indoor temperatures can be influenced by building structures constructed with brick and cement walls, as well as poor ventilation. Humidity measurements using a Bosean Air Quality Detector showed that 63% of respondents' homes had rooms with humidity levels that did not meet the standards, with an average humidity of 67.40% RH. Most homes (57.4%) had ventilation areas that met health requirements. Ventilation plays a role in maintaining oxygen balance and constant circulation. However, lighting intensity did not differ significantly between homes that met and did not meet the standards. Measurement of lighting intensity was done using a lux meter, with qualifying results of ≥ 60 lux. The concentration of $PM_{2.5}$ in 51.9% of the houses did not meet the requirements set by the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023. $PM_{2.5}$ concentrations were considered to meet the standards when measured at $< 25 \mu g/m^3$.

The chemical concentration measurements showed that formaldehyde (HCHO) levels met health requirements in 64.8% of the sampled homes. Based on the Regulation of the Minister of Health Number 2 of 2023, HCHO levels are classified into two categories: appropriate if the concentration is < 0.1 ppm and inappropriate if it exceeds > 0.1 ppm. Carbon monoxide (CO) concentrations also met the required standards, as sampling was conducted only in bedrooms where potential sources of CO were minimal. CO concentrations are typically higher in enclosed spaces with poor ventilation and exposure to cigarette smoke. However, in this study, CO levels remained within acceptable limits (≤ 9 ppm). In addition to these gaseous pollutants, total volatile organic compounds (TVOCs) also met health requirements. This may be attributed to the sampling locations being situated away from household furniture and conducted in homes that were either unpainted or had not been recently painted. Indoor TVOCs concentrations were considered non-compliant when levels exceeded > 3 ppm.

Influence of Physical Factors on the Incidence of Pneumonia

Physical environmental measurements consisted of ventilation, lighting, humidity, and temperature. Table 2 presents the results of the logistic regression analysis of the correlation between physical environmental factors and the incidence of pneumonia in children. The results indicate that temperature, humidity, lighting, and ventilation were significantly associated with the incidence of pneumonia in toddlers in the working area of the South Krembangan Community Health Center with p-values < 0.05 .

Table 2. Logistic Regression Analysis Results of the Influence of Physical Factors on Pneumonia

Variable	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Temperature	0.197	0.929	0.045	1	0.049	1.217	0.197	7.524
Humidity	-0.068	0.969	0.005	1	0.042	0.935	0.14	6.245
Lighting	1.629	1.178	1.912	1	0.048	5.098	0.507	51.312
Ventilation	0.756	0.331	5.212	1	0.022	2.13	1.114	4.074
Constant	-0.88	0.428	4.229	1	0.04	0.415		

Influence of Chemical Factors on the Incidence Pneumonia

Chemical environmental measurements included PM_{2.5}, HCHO, TVOC, and CO. Based on measurements of 54 samples, TVOC and CO concentrations were found to meet the requirements of the applicable regulations. Therefore, among the chemical factors analyzed for their influence on pneumonia in children under five, only

PM_{2.5} and HCHO were examined, as presented in Table 3. The chemical environmental factors, only PM_{2.5} was significantly associated with pneumonia in toddlers ($p = 0.011$). PM_{2.5} particles can penetrate deeply into the respiratory tract, causing inflammation and increasing susceptibility to infection. HCHO (formaldehyde) did not show a significant correlation ($p = 0.834$), indicating that it was not a risk factor for pneumonia in this study.

Table 3. Logistic Regression Analysis Results of the Influence of Chemical Factors on Pneumonia

Variable	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
PM _{2.5}	1.529	0.602	6.445	1	0.011	4.612	1.417	15.011
HCHO	1.132	0.63	0.044	1	0.834	1.142	0.392	3.924
Constant	-0.819	0.532	2.371	1	0.124	0.441		

DISCUSSION

Influence of Physical Factors on Pneumonia Incidence

Understanding the influence of physical factors, including temperature, humidity, and lighting, on pneumonia incidence among children under five is an important public health concern. Pneumonia is a lung infection caused by microbial contamination, with environmental conditions being risk factors, particularly in children under five. Unsuitable environmental conditions or room temperatures can compromise a toddler's immune system. Research shows that temperatures that are too low or too high can cause stress to the respiratory system, potentially increasing susceptibility to respiratory infections, including pneumonia (13). Room temperatures that did not meet the requirements were associated with a 4.037-fold higher risk of pneumonia, while improper humidity increased the risk by 3.769 times. Inadequate room lighting intensity was associated with a 5.641-fold higher risk, and children living in homes with inadequate ventilation were 4.256 times more likely to develop pneumonia than those whose homes had good ventilation. Formaldehyde (HCHO) levels were not significantly associated with pneumonia incidence in toddlers, with an estimated risk of 1.63 times.

Microorganisms have a favorable temperature range for reproduction, which ranges from 28°C to 30°C. At this temperature, microorganisms will grow optimally and very quickly. The longer microorganisms survive indoors, the greater their likelihood of being inhaled by

humans, thereby elevating the risk of health problems, including pneumonia. Humidity also has a significant influence on respiratory health. Excessively high humidity can create conditions that favor the growth of pathogenic microorganisms, while excessively low humidity can cause irritation to the respiratory tract (14). In this context, a significant correlation between physical environmental factors, including temperature and humidity, and the incidence of pneumonia in toddlers (14). Lighting is another important physical parameter that plays a crucial role in the incidence of pneumonia. One study found that a reduced risk of respiratory infections may be a result of reduced humidity and sufficient air circulation due to adequate room lighting (15). A similar study found that toddlers living in homes with inadequate lighting had a 2.223-fold greater risk of pneumonia compared to those living in well-lit homes that met regulatory standards (16). This can be explained by the fact that the risk of respiratory infections can increase due to environments with minimal or dark lighting and increased humidity, which ultimately facilitates the proliferation of bacteria, viruses, microorganisms, and other pathogens (14). The physical quality of the home environment, including temperature, humidity, and lighting, should be a priority in efforts to prevent pneumonia in children under five years of age (17). Other relevant studies suggest that homes with poor physical conditions such as uncontrolled room temperatures and high humidity make it easier for the occupants, especially children, to contract respiratory problems, including pneumonia (18).

To prevent and control pneumonia in toddlers due to poor physical environmental conditions, interventions aimed at improving physical environmental quality are essential (19). Overall, physical air quality factors, namely temperature, humidity, and lighting, significantly influence pneumonia (20). A study confirms that adequate physical environments actively contribute to reducing an individual's risk of developing respiratory problems, one of which is pneumonia. This cannot happen without human interventions, who must be aware and play a role in maintaining a healthy home environment so that it is safe and comfortable for family members, including toddlers (21).

Influence of Chemical Factors with Pneumonia Incidence

The results of this study indicate that $PM_{2.5}$ had a significant correlation with the incidence of pneumonia in toddlers. Particulate Matter (PM) itself is defined as particles suspended in the air in a small solid or liquid form, while aerosols are particles and gases mixed together. PM can pose health risks if inhaled, depending on the size of particles and depth of penetration into the respiratory tract (22). Certain human activities that increase the risk of particle exposure include the combustion of fossil fuels from motor vehicle exhaust or other sources. This allows pollutants to accumulate indoors and increase aerosol concentrations. Anthropogenic aerosols, which originate from human activities, currently contribute around 10% of the total aerosol load in the atmosphere (23). Another study revealed different results from this study which did not show a significant correlation between formaldehyde gas (HCHO) and pneumonia in toddlers. The study reported that houses made of wood can act as intermediaries for the increased prevalence of respiratory infections in children, especially low-quality and thin wood because it can release volatile organic compounds indoors. Composite wood materials emit formaldehyde and can worsen indoor air quality (24).

The concentration of carbon monoxide (CO) gas in a room that does not use a gas stove for cooking is around 0.5-5 ppm, while a room that uses a gas stove for cooking has a concentration of around 5-15 ppm and, in some cases, up to 30 ppm or higher. Excessive exposure to CO gas can cause serious health problems (25-26). In this study, carbon monoxide (CO) concentrations met the required standards, as most households used liquefied petroleum gas (LPG) for cooking rather than traditional fuels or biomass such as wood, crop residues, or charcoal. Carbon monoxide (CO) gas can be produced from household activities that utilize biomass fuel, with concentrations reaching up to 100 ppm/hour or higher,

which far exceeds the requirements set to be considered healthy (27). High concentrations of CO pollutants are the result of incomplete combustion activities that worsen indoor air quality, especially if the housing does not meet health standards in terms of physical conditions, including inadequate air ventilation, the absence of kitchen chimneys, or an exhaust system that does not meet health requirements (28). Therefore, the presence of CO gas is one of the chemical parameters that need to be considered in the indoor environment. CO gas that exceeds the requirements will pose negative impacts on health, because excess CO will interfere with oxygen transport to body tissues, potentially causing nervous system disorders (29).

A Canadian study showed that 10 types of volatile organic compounds (VOCs) in indoor environments are associated with decreased lung function, especially in individuals under 17 years of age (30). VOCs are pollutants frequently found in homes, originating from various sources, including interior lighting, fuel combustion, and cleaning products. VOCs are organic chemicals characterized by their ability to evaporate under normal indoor air pressure and temperature conditions (31). VOC gases in houses arise from gases released by building materials, painted wood products, household products, cleaning agents, fresheners, mothballs, and other consumer products (32). A study conducted in Texas concluded that the main sources of high indoor VOC concentrations are household cleaning agents, furniture paint, materials commonly used in arts and crafts, toilet air fresheners, and the use of hot water (32). Another study in Italy found an increase in respiratory illnesses in children living in petrochemical industrial areas due to exposure to VOCs (33).

Dust is another parameter of chemical indoor air quality that requires attention, as it originates not only from human activities, but also from natural sources and various materials (29). Indoor natural air pollution can be caused by excessive concentrations of dust particles. Another important contributor that influences air quality is cigarette smoke, especially indoors, as cigarette smoke itself releases gases and particles that can linger in the indoor environment for a long time (34). Human activities are major contributors to the generation of dust and gases, including indoor smoking, as well as the use of household products, cosmetics, and pesticides. These activities can trigger various health issues, especially respiratory problems among all family members (35). One cigarette produces around 5,000 mg of emissions, consisting of gas components (92%) and particles in the form of liquid aerosol droplets and submicroscopic solid tar particles (8%). Thousands of compounds are also

contained in cigarette smoke, including more than 1,000 reactive species in the gas phase, especially nitrogen oxides (36). Oxidants produced by tobacco smoke can reduce intracellular antioxidant levels in lung cells, and the high oxidative load in cigarette smoke plays a major role in causing airway damage (37). Aerosols entering the respiratory tract can trigger mechanisms of respiratory damage and dysfunction. These particles then produce free radicals, resulting in oxidative stress that damages lung cells and leads to inflammation (38). Aerosols can also trigger the body's immune response, resulting in pathological changes in lung tissue and chronic inflammation (39). The most dangerous impact is disruption of the normal function of lung cells that play a role in maintaining lung health, such as epithelial cells and macrophages (40).

Aerosol exposure has varied health effects, depending on factors such as particle size, duration of exposure, and chemical composition. Common health impacts include respiratory disorders such as coughing, shortness of breath, and wheezing; decreased lung function; chronic obstructive pulmonary disease (COPD); asthma exacerbations; and even lung cancer (41). Another relevant study revealed that indoor exposure to 10 types of VOCs is closely associated with decreased lung function, particularly in children and adolescents (42). Human efforts to reduce exposure to air pollutants are crucial. Several strategies can be implemented, including reducing aerosol emissions from various sources, paying closer attention to air quality, especially indoors, and using personal protective equipment such as masks, especially in poor-quality environments (43).

Research Limitations

This study has several limitations. Indoor air quality measurements focused only on specific physical and chemical parameters, and did not include biological parameters such as the presence of bacteria and fungi. Furthermore, measurements were only conducted once during the study period, thus underestimating possible daily or seasonal variations in air quality.

CONCLUSION

The incidence of pneumonia in toddlers under five years of age in the working area of the South Krembangan Community Health Center correlated significantly with several physical indoor air quality parameters, namely temperature, humidity, lighting intensity, and ventilation area. For chemical air quality parameters, only PM_{2.5} was significantly related, while HCHO, CO, and TVOC gases did not have significant correlations with the incidence of pneumonia in children

under five years of age in this study. Although the housing conditions of many respondents met the requirements, it is still necessary to pay attention to aspects that can affect physical and chemical indoor air quality to prevent negative impacts on children's respiratory health.

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AUTHORS' CONTRIBUTION

S: Conceptualization, Writing, Reviewing, Supervision. DA: Conceptualization, Methodology, Software. FAR: Writing, Reviewing, Editing. NDA: Methodology, Data Curation. DAS: Editing, Data Curation.

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